

APPLICATION FOR UNITED STATES LETTERS PATENT

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INVENTION: A PRINTING APPARATUS AND  
CARRIAGE SCAN DRIVING  
METHOD

S P E C I F I C A T I O N

This application is based on Patent Application No. 2000-17568 filed January 26, 2000 in Japan, the content of which is incorporated hereinto by reference.

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#### BACKGROUND OF THE INVENTION

#### FIELD OF THE INVENTION

The present invention relates to a printing apparatus and a carriage scan driving method. More particularly, the invention relates to a serial type printing apparatus and a carriage scan driving method scanning a carriage on a direction perpendicular to a feeding direction of a printing medium.

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#### DESCRIPTION OF THE RELATED ART

It is typical to gradually complete printing over an entire area of a printing medium by repeating printing operation, in which printing is performed by scanning the carriage and performing printing by means of a printing head mounted on the carriage upon scanning, and feeding operation in which a printing medium is fed for a predetermined amount in a direction perpendicular to scanning direction of the carriage.

Such serial type printing apparatus is controlled scanning of the carriage so that a scanning distance of

the carriage becomes the shortest depending upon a printing region in order to shorten a printing period.

Also, the carriage varies speed at three stages of acceleration stage, constant speed stage and deceleration stage during one scan, to perform printing at constant speed condition and not to perform printing at acceleration and deceleration stages. Therefore, it has been proposed to shorten printing period by performing feeding of the printing medium during acceleration and deceleration stages. For example, Japanese Patent Application Laid-Open No. 1-101173 (1989) has proposed a method to control an acceleration start timing of the carriage depending upon a period required for feeding operation of the printing medium in order to certainly complete feeding of the printing medium by the completion of acceleration of the carriage.

However, printing regions are not always the same per line and can be long in some line and short in another. In the conventional method, difference of the printing position due to difference of the printing regions per line is not taken into account in scan controlling of the carriage. Thus, the same control is applied for any lines, and whereby shortening of the printing period depending upon difference of the printing region cannot be expected.

On the other hand, in the printing apparatus of an ink-jet printing system, it is required a certain period from ejection of an ink to hitting on the printing medium.

Thus the printing apparatus is required to effect correction of arrival time to the printing medium from ejection of the ink when scanning a carriage. Therefore, the printing apparatus can not shortened a printing period 5 corresponding to that scanning period.

Furthermore, the ink jet-printing apparatus regularly performs recovery operation even during printing operation for the purpose of removal of ink of increased viscosity by ejecting operation for a plurality of times. However, in the conventional method, scan controlling of the carriage has not been performed with taking the period required for the recovery process into account to perform the same scan controlling in both scan performing recovery operation and scan not performing 10 recovery operation.

On the other hand, in not only the printing apparatus of the ink-jet printing system but also various bi-directional printing apparatus, in which scanning direction of the carriage is different per line, namely 15 printing operation is performed in both forward scan and reverse scan, it is required to make correction for deviation due to a scanning play of the carriage and a phase delay of motor or the like by scan of carriage. Shortening of printing period cannot be achieved for the period 20 required for correction set forth above.

The present invention has been worked out in view of the problem set forth above. It is an object of the present 25

invention to provide a printing apparatus and a carriage scan driving method in which printing can perform in a shorter period per printing pattern.

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## SUMMARY OF THE INVENTION

A printing apparatus of the present invention scans a carriage mounting a printing head over a printing medium for a plurality of times, to perform printing upon 10 respective scan and to perform feeding the printing medium for feeding the printing medium for a predetermined amount in a direction different from a scanning direction of said carriage between scans of plurality of times for printing on a printing medium. The printing apparatus includes 15 means for getting information relating to a printing medium feeding period required for feeding the printing medium for the predetermined amount after completion of printing in a preceding line in a preceding scan. The printing apparatus also includes means for setting a 20 carriage scanning period required to printing start of the next line after completion of printing in said preceding line so as to be substantially equal to said printing medium feeding period depending upon printing completion position of the preceding line and the printing start 25 position of the next line. The printing apparatus furthermore includes means for driving said carriage to scan depending upon a period set by said carriage scanning

period setting means.

By such construction of the present invention, the carriage scanning period is set depending upon the printing completion position of the preceding line and the 5 printing start position of the next line which are different per printing pattern, and the carriage driving means drives scanning of the carriage so that scanning of carriage upon to printing start position of the next line after completion of printing of the preceding line and 10 feeding of the printing medium in the predetermined amount are completed simultaneously. Therefore, printing can be performed at possible minimum period at respective printing pattern.

The above and other objects, features and advantages 15 of the present invention will become more apparent from the following description of embodiments thereof taken in conjunction with the accompanying drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

20 Fig. 1 is a perspective view of one embodiment of a printer according to the present invention;  
Fig. 2 is a block diagram showing a electrical construction of the printer;  
25 Fig. 3A is a diagrammatic chart showing a printing pattern 1;  
Fig. 3B is a timing chart showing operations of

respective driving portions after printing for the first line of the printing pattern of Fig. 3A to starting printing for the second line;

Fig. 4A is a diagrammatic chart showing a printing pattern 2;

Fig. 4B is a timing chart showing operations of respective driving portions after printing for the first line of the printing pattern of Fig. 4A to starting printing for the second line;

Fig. 5A is a diagrammatic chart showing a printing pattern 3;

Fig. 5B is a timing chart showing operations of respective driving portions after printing for the first line of the printing pattern of Fig. 5A to starting printing for the second line;

Fig. 6A is a diagrammatic chart showing a printing pattern 4;

Fig. 6B is a timing chart showing operations of respective driving portions after printing for the first line of the printing pattern of Fig. 6A to starting printing for the second line;

Fig. 7A is a diagrammatic chart showing a printing pattern 2 similar to Fig. 6A;

Fig. 7B is a timing chart showing operations of respective driving portions after printing for the first line of the printing pattern of Fig. 7A to starting printing for the second line;

Fig. 8A is a diagrammatic chart showing a printing pattern in the second embodiment;

Fig. 8B is a timing chart showing operations of respective driving portions after printing for the first 5 line of the printing pattern of Fig. 8A to starting printing for the second line;

Fig. 9A is a diagrammatic chart showing a printing pattern in the third embodiment;

Fig. 9B is a timing chart showing operations of 10 respective driving portions after printing for the first line of the printing pattern of Fig. 9A to starting printing for the second line;

Fig. 10A is a diagrammatic chart showing a printing pattern in the third embodiment; and

15 Fig. 10B is a timing chart showing operations of respective driving portions after printing for the first line of the printing pattern of Fig. 10A to starting printing for the second line.

20 DESCRIPTION OF THE PREFERRED EMBODIMENT

Preferred embodiments of the present invention will be explained in detail with reference to the drawings.

Fig. 1 is a perspective view of one embodiment of a 25 printer according to the present invention.

A printer 1 has a sheet feeder portion 202 feeding a printing medium 201 therefrom, a printing portion 203

performing printing for the fed printing medium 201 and a feeding portion 204 for feeding the printing medium 201.

The printing portion 203 has a carriage 205 mounting a printing head 206 (detail will be explained later).

5 During printing, the carriage 205 performs scan along a guide shaft 207. Upon scanning, ink droplet is ejected from the printing head 206 toward the printing medium 201. The carriage 205 is driven by a driving force of a carriage motor 208 transmitted via a belt 209 thereto. Also, in  
10 principle, printing is bi-directional printing.

The feeding portion 204 has a feeding roller 211 driven by a feeding motor 210 to rotate for a given magnitude to transport the printing medium 201 for a predetermined amount in a direction of arrow A. When the  
15 printing portion 203 performs one scan, the feeding portion 204 performs feeding of the printing medium for the predetermined amount. By repeating printing and feeding, printing is performed over the entire area of the printing medium 201.

20 The printing head has a head portion, in which a plurality of ejection openings are arranged and ink tank portion, in which ink is stored. The head portion and the ink tank portion are communicated with a supply passage. A plurality of ejection openings are arranged in a  
25 direction perpendicular to the scanning direction of the carriage. Each of ejection openings and the supply passages is communicated with ink passages to constantly

fill the ink up to ejection openings. On the other hand, corresponding to respective ejection openings, a heater as electro-thermal transducer, is provided. Upon ink ejection, the heater is heated to generate bubble in the 5 ink. By a pressure in generation of bubble, an ink droplet is ejected. In the shown embodiment, a bubble-jet type printing head is employed. However, the present invention is not limited to the bubble-jet type but is applicable for any type of printing methods. Furthermore, the 10 present invention is not limited to the ink-jet system but is applicable for other printing method, such as a thermal transfer type and the like.

A recovery processing portion 212 performs a preparatory ejection process for ejecting the ink from the 15 nozzle of the printing head 206 in a region other than a printing region, a suction process for sucking the ink from the nozzle by a pump or the like, and a wiping process for cleaning the surface of the nozzle.

Fig. 2 is a block diagram showing an electrical 20 construction of the printer.

CPU 31 performs drive control of respective driving portion of the printer. This is performed in response to an operation command input by a user through an operation panel 302 or a printing data or a printing command from 25 a host computer 304 input through an interface portion (I/F) 303.

Driving of respective driving portion is performed

by reading out program stored in a non-volatile program memory 305 and according to the read out program. On the other hand, a volatile data memory 306 temporarily stores record data transferred from the host computer 304 and is  
5 also used as a work memory during process.

Drive commands output from CPU 301 to respective driving portions is fed to the driving portions through respective driver. The feeding motor 310 is driven according to a command from a feeding motor driver 307.

10 The carriage motor 311 is driven according a command from a carriage motor driver 308. The printing head 312 is driven according to a command from a head driver 309.

Next, drive control for respective driving portion will be explained.

15 In the shown embodiment, depending upon a pattern to be printed, driving from completion of preceding operation of the carriage to start of next scan is differentiated to control scanning of the carriage so that scanning distance of the carriage becomes minimum. Hereinafter,  
20 driving method will be explained per printing pattern. It should be noted that the shown embodiment of the printer is designed to perform bi-directional printing as set forth above, and in general, for performing printing for first line by forward scan and printing for second line  
25 by reverse scan.

(1) Pattern 1: When printing is performed over entire printing regions both in first and second lines

A printing pattern shown in Fig. 3A shows the case where printing is to be performed over the entire printing regions both in the forward scan (first line) and the reverse scan (second line). A printing width  $t$  in one scan 5 corresponds to a width of ejection openings array of the printing head.

Fig. 3B is a timing chart showing a behavior of the printing head, the carriage and the feeding motor upon transfer to printing of the second line after printing of 10 the first line in the said printing pattern.

The timing chart of the printing head represents driving condition of the printing head when the chart is present at upper side and non-driving condition of the printing head when the chart is present at lower side.

15 The timing chart of the carriage (CR) shows forward scanning speed by positive direction from 0 and reverse scanning speed by negative direction from 0. Speed 0 represents resting condition of the carriage.

20 The timing chart of the feeding motor (LF) represents feeding or feeding speed in positive direction. Speed 0 represents feeding stop condition.

Transfer operation from printing for the first line to printing for the second line will be explained with reference to the timing chart.

25 At the completion of printing in the forward direction, namely, when driving of the printing head is stopped ( a point ① of Fig. 3B), the feeding motor is simultaneously

driven. It should be noted that drive timing of the feeding motor is preliminarily set depending upon a period required from ejection of the ink droplet to hitting on the printing medium. The feeding motor feeds the printing 5 medium for a predetermined amount at a constant speed condition via accelerating condition.

After termination of driving of the printing head, the carriage is driven to travel with maintaining the current speed for a predetermined period  $T_{ctrl}'$ , and 10 subsequently enters into deceleration state to stop (at point ② of Fig. 3B). The reason to maintain the constant speed for the predetermined period  $T_{ctrl}'$  is to adapt to a play of the carriage driving system or a phase delay of the motor, or, in the alternative, to correct the drive 15 timing of the printing head depending upon the printing direction depending upon arrival timing of the ink to the printing medium by driving of the printing head. It should be noted that such correction may be achieved not only by providing extra period of constant speed driving but also 20 by performing correction depending upon scanning distance or position of the carriage. Also, in the shown embodiment, constant speed state is maintained for the predetermined period  $T_{ctrl}'$ , when the value of  $T_{ctrl}'$  is large, it is possible to accelerate during this period.

25 Next, after stopping for a waiting period  $T_{wait}$  derived through calculation discussed later (point ③ of Fig. 3B), the carriage is accelerated in the reverse

direction. After end of acceleration, the carriage is driven at a constant speed for a predetermined period  $T_{cr2}'$ . Thus, the carriage reaches the print start position (point ④ of Fig. 3B). Here, a period required from completion 5 of printing of the first line to start printing of the second line (including deceleration and stop period, acceleration period, waiting period and preparatory ejection period and so forth) will be referred to as "carriage scanning period". When the carriage reaches the 10 print start position, the printing head starts printing operation for the reverse direction. It should be noted that a period  $T_{cr2}'$  similarly to  $T_{cr1}'$  is a period provided for compensation of the play of the carriage or the phase delay of the motor. These  $T_{cr1}'$  and  $T_{cr2}'$  are not 15 necessarily provided at the end of forward scan and before scanning in the reverse direction and can be either one for adjustment.

The feeding motor starts driving in response to end 20 of driving of the printing head for feeding the printing medium for a predetermined amount. However, after driving of the feeding motor is terminated, the motor per se is still rotated due to inertia force and the driving system is still maintained driving, or the feeding system such as feeding roller is still acted with inertia moment.

25 Then a period  $T_{lf2}$  is required for completely stopping of the printing medium. In practice, when a pulse motor is employed as the feeding motor, after driving of the pulse

motor for a predetermined number of pulses, stopping of feeding of the printing medium can be ensured by maintaining the finally excited phase for the period  $T_{1f2}$ .

On the other hand, when a DC motor is employed as the feeding motor, it becomes possible to certainly detect stopping of feeding of the printing medium by making judgment of stopping of vibration of the feeding roller by providing a sensor in a printing medium feeding path for detecting angular position of the feeding roller, for example.

10 Furthermore, when a driving force transmitting means is interposed between the feeding roller and the feeding motor, a difference of timing is caused from judgment of stopping by the sensor to stopping of the feeding roller as set forth above. Therefore, stopping of feeding of the 15 printing medium can be certainly performed by making judgment of stopping of the printing medium after elapse of the predetermined period.

As set forth above, the period  $T_{1f}$  is required for feeding the printing medium for a predetermined amount, 20 and adjustment has to be made to place the carriage at a predetermined position within this period. This adjustment is done by adjusting a waiting period  $T_{wait}$  in which the carriage is held stopped. Hereinafter, a method for deriving  $T_{wait}$  in the printing pattern of Fig. 3A will 25 be explained.

At first, a period required for feeding the printing medium per one scan, namely a period  $T_{1f}$  required from

driving of the feeding motor to stopping of the printing medium (hereinafter referred to as "printing medium feeding period") is calculated. The printing medium feeding period is determined by a printing medium feeding amount depending upon the printing pattern.

Next, at every completion of one scan of the carriage, a deceleration stop period  $T_{cr1}$  including the deceleration correction period  $T_{cr1}'$  is determined.

On the other hand, a carriage acceleration period  $T_{cr2}$  including the acceleration correction period  $T_{cr2}'$  from stopping of the carriage to starting of next scan is derived. With the value thus derived,  $T_{wait}$  is derived.

It is assumed that when  $T_{lf} > T_{cr1} + T_{cr2}$ ,  $T_{wait} = T_{lf} - (T_{cr1} + T_{cr2})$ , and when  $T_{lf} \leq T_{cr1} + T_{cr2}$ ,  $T_{wait} = 0$ .

Namely, when  $T_{lf} > T_{cr1} + T_{cr2}$ , the carriage scanning period becomes equal to the printing medium feeding period with providing the waiting period. On the other hand when  $T_{lf} \leq T_{cr1} + T_{cr2}$ , the carriage scanning period is adjusted to be as close as possible with setting the waiting period at 0. In this meaning, in either case, the carriage scanning period is substantially adjusted to be substantially equal within the printing medium feeding period.

Accordingly, when the carriage scanning period ( $T_{cr1} + T_{cr2}$ ) from the completion of printing of the first line to starting of the printing of the second line is greater

than the printing medium feeding period  $T_{lf}$ , the carriage is driven for scanning without no waiting period ( $T_{wait}$ ). On the other hand, when the carriage scanning period from the completion of printing of the first line to starting of the printing of the second line ( $T_{cr1} + T_{cr2}$ ) is smaller than the printing medium feeding period  $T_{lf}$ , the waiting period ( $T_{wait}$ ) is provided between scanning of the carriage for the first line and the second line. Thus, immediately after printing medium feeding period  $T_{lf}$  completes, printing for the second line is initiated. Accordingly, printing can be performed at a possible minimum period irrespective of the printing pattern.

It should be noted that in the foregoing method, the waiting period ( $T_{wait}$ ) is derived on the basis of the carriage scanning period  $T_{cr1}$  and  $T_{cr2}$  and the printing medium feeding period  $T_{lf}$ , which are predetermined. However, for example, when the carriage is operated by a DC motor servo-mechanism or the like, it is possible to cause individual difference in carriage scanning period per the printing apparatus. In such case, in deriving the period  $T_{cr1}$  from completion of printing for the first line to stopping the carriage, it becomes possible to accurately calculate by measuring a period actually required for stopping the carriage after stopping driving of the motor and by using the actually measured period. And, concerning the carriage scanning period  $T_{cr2}$  from acceleration of the carriage to starting of printing for

the second line, the printing period can be shortened because printing for the second line is not initiated before stopping of feeding of the printing medium by using a period with taking an individual difference of the 5 carriage scanning period into account.

As set forth above, even when the DC servo-mechanism is employed in the feeding motor, the printing period can be shortened because printing for the second line is not initiated before stopping of feeding of the printing 10 medium by similarly using a period with taking an individual difference of the carriage scanning period into account.

Furthermore, by checking whether the printing medium is completely stopped or not at a timing of starting of 15 printing for the second line, it may be possible to stop printing operation when the printing medium is not stopped completely so as to avoid inappropriate printing.

(2) Pattern 2: When print start position for the second line is shifted for a distance D

20 The printing pattern of Fig. 4A is advanced the print start position for the second line for a distance D from the print start position as illustrated in Fig. 3A.

Fig. 4B is a timing chart for printing the printing pattern of Fig. 4A.

25 The timing chart from completion of printing for the first line (point ① of Fig. 4B) to stopping the carriage (point ② of Fig. 4B) is the same as that of the pattern

1.

Since the feeding amount of the printing medium is similar to the pattern 1, driving of the feeding motor is similar to the pattern 1.

5 Since the printing pattern 2 is advanced for the distance D in comparison with the printing pattern 1, the carriage is required to move for an extra length corresponding to the shifted distance before starting of driving of the printing head. Accordingly, a period  $T_{cr2}''$  required to place the carriage upon printing start position for the second line becomes a sum of the carriage acceleration period  $T_{cr2}$  (including the acceleration correction period  $T_{cr2}'$ ) and a period  $T_{cr3}$  required for scanning the distance D at constant speed.

10 15 Similarly to the pattern 1,  $T_{cr1}$ ,  $T_{cr2}''$  and  $T_{lf}$  are derived depending upon the printing medium feeding amount depending upon the performances of feeding motor and the carriage motor and the printing pattern.

20 Then, when  $T_{lf} > T_{cr1} + T_{cr2}''$ , the waiting period ( $T_{wait}$ ) is derived by  $T_{wait} = T_{lf} - (T_{cr1} + T_{cr2}'')$ . In case of  $T_{lf} \leq T_{cr1} + T_{cr2}''$ ,  $T_{wait} = 0$ .

25 As set forth above, by deriving the period  $T_{wait}$ , driving of the carriage is controlled according to the derived value. By this, in comparison with the pattern 1, the printing period can be shortened for the period of  $T_{cr3}$ .

On the other hand, when the first line is shorted than

the second line in the extent of the distance D, a period from the print end timing for the first line (point ① of Fig. 4B) to the deceleration and stop point (point ② of Fig. 4B) becomes longer than that in the pattern 1 in the 5 extent of Tcr3, and a period from carriage acceleration start point (point ③ of Fig. 4B) to the print start timing for the second line (④ of Fig. 4B) becomes equal to that of the pattern 1. Therefore, even in this case, the printing period can be shortened for Tcr3 in comparison 10 with the pattern 1.

(3) Pattern 3: When printing positions in the first line and the second line do not overlap with each other (I)

The printing pattern of Fig. 5A does not have portion where the printing positions in the first line and the 15 second line are overlapping. In this case, without reversing the scanning direction of the carriage, two lines are printed in one scan. Furthermore, in the shown pattern, a distance s from the printing completion of the first line to the printing completion of the second line 20 is long.

Fig. 5B is a timing chart of the pattern 3.

A period Tcr4 required for scanning the distance s is derived. Then, the derived period Tcr4 is compared with the period Tlf required for feeding the printing medium 25 for one line. If  $Tlf \leq Tcr4$ , feeding of the printing medium can be completed while the carriage travels for the distance s. Accordingly, in such printing pattern, after

completion of printing of the first line (point ① of Fig. 5B), the carriage continues travel without stopping to start printing of the second line.

It should be noted that while the carriage is driven to travel at constant speed in the shown timing chart, printing period can be further shortened by doubling the scanning speed within a range of  $T_{lf} \leq T_{cr4}$ .

(4) Pattern 4: When printing positions in the first line and the second line does not overlap with each other (II)

The printing pattern of Fig. 6A does not have portion where the printing positions in the first line and the second line are overlapping. In the similar manner as the pattern 3, without reversing the scanning direction of the carriage, two lines are printed in one scan. Furthermore, in the shown pattern, a distance  $s$  from the printing completion of the first line to the printing completion of the second line is relatively short.

Fig. 6B is a timing chart of the pattern 4.

A period  $T_{cr4}$  required for scanning the distance  $s$  is derived. Then, the derived period  $T_{cr4}$  is compared with the period  $T_{lf}$  required for feeding the printing medium for one line. If  $T_{lf} > T_{cr4}$ , feeding of the printing medium can not be completed while the carriage is completed to travel for a distance  $s$ . Therefore, the carriage travels to require the waiting period  $T_{wait}$  until feeding of the printing medium is completed.

Therefore, after completion of printing of the first

line (point ① of Fig. 6B), the carriage is once decelerated and stopped. It is assumed that the period required for stopping the carriage is Tcr5. It should be noted that, 5 at this timing (point ② of Fig. 6B), the carriage is stopping at a point E of Fig. 6A. On the other hand, it is assumed that a period required for accelerating the carriage and reaching the printing start position of the second line (point F of Fig. 6A) is Tcr6.

On the other hand, after completion of printing of 10 the first line, a period required for feeding the printing medium for the predetermined amount is Tlf.

These Tlf, Tcr5 and Tcr6 are calculated depending upon the printing medium feeding amount corresponding to the performances of the carriage motor and the feeding motor 15 and the printing pattern.

Then, when  $Tlf > Tcr5 + Tcr6$ , Twait is calculated by  $Twait = Tlf - (Tcr5 + Tcr6)$ . In the alternative, when  $Tlf \leq Tcr5 + Tcr6$ , Twait is set as  $Twait = 0$ .

By controlling driving of the carriage depending upon 20 respective values thus calculated, a period required for printing can be shortened.

In the pattern 4, the timing chart of the mode where the carriage is stopped temporarily is described. However, in such printing pattern, it is possible to take a mode 25 where the carriage is decelerated to drive at low speed without stopping.

Fig. 7B is a timing chart of the case where the carriage

is not stopped in the pattern 4.

After completion of printing of the first line (point ① of Fig. 7B, a period  $T_{cr5'}$  required for decelerating the carriage to a predetermined speed and a period  $T_{cr6'}$  required for accelerating the carriage from the predetermined low speed to the normal carriage scanning speed and reaching second line printing start position (point F of Fig. 7A) are calculated. Then, low speed scanning period  $T_{cr7}$  of the carriage is determined so that  $T_{lf} < T_{cr5'} + T_{cr6'} + T_{cr7}$  is established. Thus, the carriage can be reached to the print start portion of the second line without stopping the carriage.

In the conventional method, irrespective of the printing pattern, an equal period has been required from completion of printing of one line to transit to printing of next line. However, by controlling driving and stopping of the carriage depending upon the printing pattern as in the shown embodiment, it becomes possible to shorten a period from stopping of feeding of the printing medium to starting of printing of the next line and to achieve efficient carriage travel and printing medium feeding.

It should be noted that when the interval of the printing positions of the first line and the second line in width direction is smaller than the distance necessary for deceleration, stop and acceleration of the carriage, the carriage has to be driven in reverse direction even

when the printing pattern is the patterns 3 and 4. This method is similar to the conventional method to minimize scanning of the carriage depending upon the printing pattern.

5 (Second Embodiment)

The first embodiment has been discussed in terms of the printer having capability of bi-directional printing. In the bi-directional printing, error of printing position may be caused between the line printed by the forward scan 10 and the line printed by the reverse scan, or to cause phase error in reverse scan due to vibration during scanning of the carriage, to cause fluctuation of image quality or the like. Accordingly, in order to improve image quality, it has been spreading printing method to make the scanning 15 in the same direction when the printing patterns are located adjacent with each other in feeding direction of the printing medium. In the alternative, printers of uni-directional printing, in which scanning direction is constantly one direction, have also been spreading. In 20 the shown embodiment, the carriage drive controlling depending upon the printing pattern in the case where printing is performed by scanning the carriage in the same direction.

Fig. 8A is the shown embodiment of a printing pattern.

25 Fig. 8B is a timing chart of respective driving portion upon transfer from the first line to the second line of the foregoing printing pattern.

When printing of the first line is completed (point ① of Fig. 8B), the feeding motor is driven to feed the printing medium for a predetermined amount. A period required for feeding the printing medium for a predetermined amount is assumed to be  $T_{lf}$ . This is the same as the first embodiment.

Upon completion of printing of the first line, the carriage is decelerated in travel in the direction A and stopped (point ② of Fig. 8B). This deceleration and stop period is assumed to be  $T_{cr8}$ .

The carriage turns the scanning direction to the direction B for scanning in reverse direction to return to the predetermined position (from point ② to point ③ of Fig. 8B). Since this reverse travel is travel not relating to printing, carriage often travels at higher speed than the carriage speed in normal printing, and is referred to as carriage return. A period required for reverse travel, namely a return period is assumed to be  $T_{cr9}$ .

In order to reach the printing start position of the second line at a predetermined speed, the carriage starts acceleration from an acceleration start position (point ④ of Fig. 8B) to reach the printing start position at the predetermined speed upon initiation of driving of the printing head (point ⑤ of Fig. 8B). This acceleration period is assumed to be  $T_{cr10}$ .

In order to simultaneously complete reaching of the

predetermined speed of the carriage and completion of feeding of the printing medium at the point ⑤, the waiting period  $T_{wait}$  is provided in order to match scanning of carriage to feeding of the printing medium, in similar manner as the first embodiment. This  $T_{wait}$  is derived in the following manner.

At first,  $T_{cr8}$ ,  $T_{cr9}$ ,  $T_{cr10}$  and  $T_{lf}$  are calculated depending upon the performances of the feeding motor and the carriage motor and the printing medium feeding amount 10 depending upon the printing pattern. Then, when  $T_{lf} > T_{cr8} + T_{cr9} + T_{cr10}$ , the waiting period is calculated by  $T_{wait} = T_{lf} - (T_{cr8} + T_{cr9} + T_{cr10})$ , and when  $T_{lf} \leq T_{cr8} + T_{cr9} + T_{cr10}$ ,  $T_{wait} = 0$  is set.

Namely, when the printing medium feeding period  $T_{lf}$  15 is shorter than the carriage scanning period ( $T_{cr8} + T_{cr9} + T_{cr10}$ ) from completion of printing of the first line to printing start of the second line, the carriage is driven without the waiting period. On the other hand, when the printing medium feeding period  $T_{lf}$  is longer than the 20 carriage scanning period ( $T_{cr8} + T_{cr9} + T_{cr10}$ ) from completion of printing of the first line to printing start of the second line, the waiting period  $T_{wait}$  is provided between carriage travels for the first and second lines, thereby being able to instantly start printing of the 25 second line at the timing of completion of feeding of the printing medium. Accordingly, irrespective of the printing pattern, printing can be performed at minimum

period.

(Third Embodiment)

When the printing head is an ink-jet printing type, by repeated ejecting operation, viscosity of the ink around the ejection opening is increased to cause variation of condition of the ejection opening to affect for hitting position of the ink droplet. Therefore, recovery process is regularly performed during printing operation. The most typical recovery process is "preparatory ejection process" to move the printing head to a position out of printing region, such as home position or the like and to perform ejection in place. In the shown embodiment, application of the present invention for the printer performing preparatory ejecting process, will be explained.

In the printing pattern shown in Fig. 9A, a preparatory ejection position is provided outside of the printing region to perform preparatory ejection when the printing head reaches the preparatory ejection position after completion of printing of the first line.

Fig. 9B is a timing chart upon printing of the printing pattern of Fig. 9A.

At a timing of completion of printing of the first line (point ① of Fig. 9B), the feeding motor initiates feeding of the printing medium for the predetermined amount. The period required for feeding the printing medium in the predetermined amount is assumed to be  $T_{lf}$ .

This is the same as the first embodiment.

Upon completion of printing of the first line, the carriage is moved, decelerated and stopped at the preparatory ejection position (point ② of Fig. 9B). The 5 deceleration and stop period is assumed to be  $T_{cr11}$ .

When the carriage reaches the preparatory ejection position, the printing head performs preparatory ejection (from point ② to point ③ of Fig. 9B). The preparatory ejection period is assumed to be  $T_m$ .

10 When preparatory ejection is completed, acceleration of carriage is initiated so as to reach the printing start position of the second line at the predetermined speed (point ④ of Fig. 9B), to reach the printing start position at the predetermined speed upon driving of the printing 15 head (point ⑤ of Fig. 9B). The acceleration period is assumed to be  $T_{cr12}$ . However, when acceleration is initiated immediately after finishing of the preparatory ejection, it is possible to reach the printing start position before completion of feeding of the printing 20 medium. Therefore, in the similar manner as the first and second embodiments, the waiting period  $T_{wait}$  is provided after finishing of preparatory ejection. Calculation of  $T_{wait}$  is performed hereinafter.

Similar to the first and second embodiments,  $T_{cr11}$ , 25  $T_{cr12}$ ,  $T_m$  and  $T_{lf}$  are calculated depending upon the performances of the feeding motor and the carriage motor and the printing medium feeding amount depending upon the

printing pattern. Then, if  $Tlf > Tcr11 + Tcr12 + Tm$ , the waiting period is calculated by  $Twait = Tlf - (Tcr11 + Tcr12 + Tm)$ . On the other hand, if  $Tlf \leq Tcr11 + Tcr12 + Tm$ , the waiting period  $Twait$  is set at  $Twait = 0$ .

5       Namely, when the printing medium feeding period  $Tlf$  is shorter than a sum of the carriage scanning period ( $Tcr11 + Tcr12$ ) from completion of printing of the first line to starting of printing of the second line and the preparatory ejection period  $Tm$ , the carriage is driven to travel  
10      without the waiting period. On the other hand, when the  $Tlf$  is longer than the sum, the waiting period of the carriage is provided so that printing can be initiated immediately after finishing of feeding of the printing medium. Accordingly, even when recovery process of the  
15      printing head, such as preparatory printing is performed, printing can be performed at the shortest period.

On the other hand, in the same printing pattern shown in Fig. 10A, even in the mode where order of the preparatory ejection and waiting is reversed, that is, when the  
20      carriage reaches the preparatory ejection position (point ② of Fig. 10B), the waiting period  $Twait$  is first provided without initiating preparatory ejection and the preparatory ejection is performed subsequently, similar effect can be obtained.

25      In the embodiments shown in Figs. 9A to 10B, after completion of printing of the first line, feeding of the printing medium is initiated depending upon the printing

pattern and the carriage is simultaneously moved to the preparatory ejection position. At a timing of the preparatory ejection, when the printing completion position is close to the preparatory ejection position and 5 the preparatory ejection position is located at the same direction as the scanning direction upon printing, wasteful carriage scanning can be eliminated. In the shown embodiment, after completion of printing of the first line, preparatory ejection is performed. Namely, 10 after completion of printing of the odd number line, preparatory ejection is performed. It should be noted that the preparatory ejection position is not necessarily provided at one side but can be provided at both sides of the printing region.

15 A construction, in which the embodiments of Figs. 9A to 10B and the embodiment of Figs. 8A and 8B are combined, may also be established in accordance with the present invention.

As set forth above, by employing the printing 20 apparatus and carriage scan controlling method according to the present invention, the carriage scanning period is set depending upon the printing completion position of the preceding line and the printing start position of the next line which are different per printing pattern, and the 25 carriage control means controls scanning of the carriage so that scanning of carriage upon to printing start position of the next line after completion of printing of

the preceding line and feeding of the printing medium in the predetermined amount are completed simultaneously. Therefore, printing can be performed at possible minimum period at respective printing pattern.

5        The present invention has been described in detail with respect to preferred embodiments, and it will now be apparent from the foregoing to those skilled in the art that changes and modifications may be made without departing from the invention in its broader aspect, and  
10      it is the intention, therefore, in the apparent claims to cover all such changes and modifications as fall within the true spirit of the invention.